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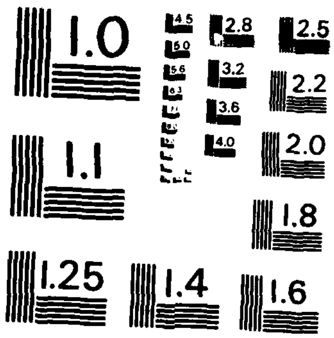

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Report USAFSAM-TR-84-7

DELAYED EFFECTS OF PROTON IRRADIATION IN MACACA MULATTA

III. GLUCOSE INTOLERANCE

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March 1984

Interim Report for Period 1964 - 1983

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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NOTICES

This interim report was submitted by personnel of the Radiation Biology Branch, Radiation Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job orders 1921E18C and 775704Y1.

The animals involved in this study were procured, maintained, and used in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals" prepared by the Institute of Laboratory Animal Resources - National Research Council.

This report has been reviewed and is approved for publication.

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A group of rhesus monkeys is being studied in a lifetime survey of the delayed effects of proton irradiation. The animals were exposed during the period 1964 - 1969 to single total-body doses of protons covering the spectrum of energies and total doses that might be expected to occur in space during a major solar flare event. This report describes the results of intravenous glucose tolerance test and the insulin response to glucose challenge in 106 irradiated animals, their control group of 42, and 10 younger control animals. The results indicate that the clearance rate of blood glucose is influenced by the age of the animal and by the type and energy of the radiation. Animals receiving greater than 360 rads of proton irradiation of energies above 138 MeV had significantly slower glucose clearance than nonirradiated controls. Seventeen-twenty-year-old controls were less glucose tolerant than 9-11-year-old controls. Animals with normal glucose tolerance showed considerable individual variation in insulin response, while in animals with marked glucose intolerance (clearance rate < 1.0 %/min), low insulin response was a consistent finding.

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DELAYED EFFECTS OF PROTON IRRADIATION IN *MACACA MULATTA*
III. GLUCOSE INTOLERANCE

INTRODUCTION

The delayed effects of space radiation are of concern to the Air Force because extended manned operations in earth orbit may expose aircrews to significant levels of particulate radiation of solar and cosmic origin (3). Identification of the latency and dose-response relationship of these biological effects is critical to the development of criteria for safe exposure limits and radiation protection measures. This study is a part of a project begun in 1964 and jointly sponsored by the U.S. Air Force and the National Aeronautics and Space Administration. The design and history of the project has been described in earlier reports in this series (10,11). A group of young rhesus monkeys of both sexes was exposed to monoenergetic protons (32, 55, 138, 400, and 2300 MeV) representative of the proton-energy spectrum in space. The 32- and 55-MeV protons have average tissue-penetration depth of 1.0 and 2.5 cm respectively, while the higher energies provide a homogeneous depth-dose distribution along a total-body penetrating path. This report describes the relationship between the type and energy of radiation exposure and the development of impaired blood glucose clearance (glucose intolerance).

TECHNICAL BACKGROUND

Maturity-onset diabetes mellitus is a common and debilitating disease of humans. It also occurs spontaneously in rhesus monkeys, although the number of reports is too small to permit accurate estimation of the incidence in this species (4,5,6). The disease is a complex metabolic disorder affecting many organs and tissues; however, the signs on which clinical diagnosis is based are the diminished capacity to metabolize glucose indicated by high concentration of glucose in the blood and a decrease in the rate of clearance of exogenous glucose from the peripheral circulation. Normal glucose metabolism does not occur without adequate insulin, a polypeptide hormone produced by the pancreas. Insulin is required for the transport of glucose from the extracellular fluid into the cells, for glycogen synthesis and glucose phosphorylation. Insulin deficiency allows abnormal accumulation of glucose in the circulating blood. Insulin is released into the circulation in response to exogenous glucose absorbed from the gut. Insulin release may also be stimulated by direct infusion of glucose into the blood, but the response is not as great as that produced by oral administration (2). Adult-onset diabetes mellitus is characterized by low insulin response to glucose challenge as well as by glucose intolerance and hyperglycemia. Recent surveys in humans have provided evidence that the magnitude of the insulin response is genetically determined and that some low insulin responders may have normal glucose tolerance and blood glucose levels (7). This finding has prompted speculation that in low insulin responders, sensitivity to insulin at the cellular level has increased to compensate for the insulin lack. Decompensation occurs when cellular sensitivity to insulin is lost because of pregnancy, obesity, aging, or other external factors. The high incidence of adult onset hyperglycemia identified during the periodic physical examination in the chronic radiation colony suggested that total-body radiation may be such a factor (9). Since the establishment of the chronic radiation colony, 35 animals have been identified as hyperglycemic (defined as having fasting serum glucose levels greater than 200 ml/dl on two consecutive examinations). All but one had been irradiated. At the present time 15 hyperglycemic animals (14 irradiated, 1 control) remain alive. Since glucose tolerance decreases in older animals, it is possible that the observations reflect an acceleration of certain biochemical processes associated with aging. Regardless of whether the effect is due to premature aging or to another specific radiation-induced injury, it is important to test the hypothesis that the frequency of hyperglycemia in low insulin responders is increased by total-body irradiation. If it can be shown that a segment of the population is genetically susceptible to radiation-induced diabetes, and that these individuals can be identified by their insulin response to glucose challenge, the information could influence the selection criteria, exposure limits, and protective measures for crew members in extended earth orbit missions.

MATERIALS AND METHODS

Design

One hundred ninety-eight animals (42 controls, 106 proton exposed, and 50 other radiation types) comprising the population of the chronic radiation colony plus ten 9-11-year-old nonirradiated subjects were tested in groups of 5 over a 20-week period. Test subjects were randomly selected with respect to radiation exposure, but the group of animals with a history of hyperglycemia were sampled first to reduce the probability of any deaths prior to tests. Testing was done between 8 a.m. and 10 a.m. each day.

Schedule

Food was withheld from the subjects for 16 hours prior to testing. Animals were immobilized with a single intramuscular dose of ketamine HCl, 15 mg/kg. A 19-g indwelling venous catheter was inserted in a leg vein, and 6-ml blood samples were drawn before glucose administration and every 12 minutes after administration for 1 hour. The dose of glucose was 0.5 g/kg body weight in 50% solution. Catheters were kept filled with heparinized saline to prevent clotting. Additional ketamine was given intravenously in 5 mg/kg increments as required for adequate restraint.

Laboratory Procedures

Blood glucose was measured by an automated (Technicon) modification of the method described by Brown (1). Insulin determination was done by commercial radioimmunoassay kit (New England Nuclear Radiopharmaceutical Corp). Serum was frozen and stored until a convenient number for analysis had accumulated.

In addition to the glucose and insulin measurements, glucose clearance rate was expressed as the percent of the circulating blood glucose disappearing per minute after injection, assuming a logarithmic disappearance curve and applying a least-squares regression line to determine the half life of the blood glucose. The insulin response was determined by calculating the area under the insulin response curve, using the fasting insulin level as a baseline.

Data Analysis

A multivariate analysis of variance (MANOVA) was employed using as components each subjects' fasting blood glucose (FBG), fasting insulin (FI), glucose clearance (K) and insulin response (IR). Three age groups of nonirradiated control animals were available for testing. Their ages, group sizes, averages and standard errors of all experimental parametersare given in Table 1. No interaction between age and sex was noted (p=.1244, Roy's maximum root test). There were no differences between 17- and 20-year-old control animals in any of the four measurements at the .05 level of significance; therefore, these two groups were combined to form one group of "old controls" of both sexes.

Results

The 9-11-year old controls had a higher mean glucose clearance rate than the 17-20-year-old group. Among all controls, males had higher fasting blood glucose and lower total insulin response than females (Table 1).

Table 2 gives the sample sizes available in the original proton studies by dose, energy, and sex. Table 3 presents the average measurements for each energy when all doses are combined. Table 4 contains the average measurements for each dose when all energies are combined.

Comparisons of energies were made by a 2-factor MANOVA (SEX X ENERGY) with the inclusion of the combined controls forming a sixth energy group. Doses were compared by a 2-factor MANOVA (SEX X DOSE) with the combined controls forming a fifth dose level. By combining doses in comparing the energies (or by combining energies in comparing the doses), we have increased our sample sizes and enhanced the chance of finding significant effects. This screening procedure allows us to see if anything unusual is occurring. It is in the following testing that we pinpoint whether the significance is attributed to specific energy or dose. Interaction was tested first by Roy's maximum root test. When significant, it indicates that males and females did not respond in the same way to either the energies or the doses. In those cases where interaction was present, separate 1-factor MANOVA models were fit. In either event Bonferroni simultaneous test procedures compared all possible pairs for significance between factor levels.

A SEX X ENERGY interaction was detected in examining all energies at once. The separate analysis for the males found the 2300-MeV fasting blood glucose level greater than both the 55- and 400-MeV levels (α=.05). Average glucose clearance among the 400-MeV subjects was also less than the 55-MeV subjects. The separate analysis for females found average fasting blood glucose levels in both the 400-MeV subjects and controls to be significantly less than the 32-MeV (α=.05). Comparison of the sexes at each of the six energy levels showed a slightly higher fasting blood glucose in control males (α=.10); no significant differences between the sexes at 32 MeV; higher fasting blood glucose levels in females at 55 MeV (α=.05); slightly lower glucose clearance in females at 138 MeV (α=.10); lower fasting insulin and insulin response in 400-MeV males (α=.05); and lower fasting insulin levels in 2300-MeV males (α=.05).

SEX X DOSE interaction was not observed when all doses were examined at once. A comparison of dose levels led to no significant findings. Comparison of the sexes led to the observation that both fasting insulin levels and insulin response times were significantly lower in the males (α=.05). A separate analysis for each sex indicated 360-400-rad male fasting insulin levels were less than control males; and 500-650-rad female fasting blood glucose levels were significantly higher than female controls (α=.05). Sex comparisons by individual doses found 200-280-rad males with lower fasting insulin levels than the females (α=.01). At 25-113-rads, males had slightly higher average insulin response levels (α=.10).

Tables 5 - 8 present the average measurements for each variable by dose, energy, and sex. In an attempt to eliminate the variability between energies, separate MANOVAs compared the various dose levels within a given energy for dose and sex effects where possible. Similarly, separate MANOVA's compared the various energies within a given dose grouping. Testing was accomplished as before; i.e., a 2-factor model was fit; when interaction was detected, 1-factor models were used; in either case, Bonferonni's simultaneous testing examined all possible pairs. Table 9 summarizes the statistically significant differences for all parameters among all combinations of dose and energy. In addition, the 400-MeV male insulin response was less than the females (α=.05).

Data were also grouped to contrast totally penetrating (138-2300 MeV) energies with the partially penetrating (32-55 MeV) energies. Initially, a 4 x 2 x 2 (DOSE, ENERGY, SEX) MANOVA was examined with dose levels of 25-113 rads, 200-280 rads, 360-400 rads, and 500-650 rads. Table 10 summarizes means and sample sizes for these respective groupings. Both DOSE X ENERGY (α=.05) and DOSE X ENERGY X SEX (α=.01) interactions were present. Accordingly, each sex was analyzed separately in a 4 x 2 x 1 design.

No DOSE X ENERGY interaction was present in the males (α=.05). A comparison of the higher with the lower energies revealed greater fasting blood glucose levels in the higher energies (α=.05) and shorter glucose clearance and insulin response times in the higher energies (α=.05). No dose effects could be detected by this design (α=.05).

A DOSE X ENERGY interaction was present in the females (α=.05). The only significant contrasts between high- and low-energy groups occurred in fasting insulin in the 25-113-rad range and glucose clearance in the 360-400-rad range. In the former case, the fasting insulin levels were higher in the totally penetrating; while in the latter case, glucose clearance times were longer in the lower penetrating energies. The only detectable dose difference was lower fasting insulin levels in the 360-400-rad high-energy group compared to the 200-280-rad high-energy subjects.

When the data are divided into normal ($K \geq 2$), borderline ($1 \leq K < 2$), and diabetic ($K < 1$) groups (Fig. 1), the differences in proportions between control and irradiated subjects in each group were not statistically significant (chi-square). However, the proportion of controls with normal clearance rates was greater than the exposed.

A complete table of data on all subjects is included as Appendix A.

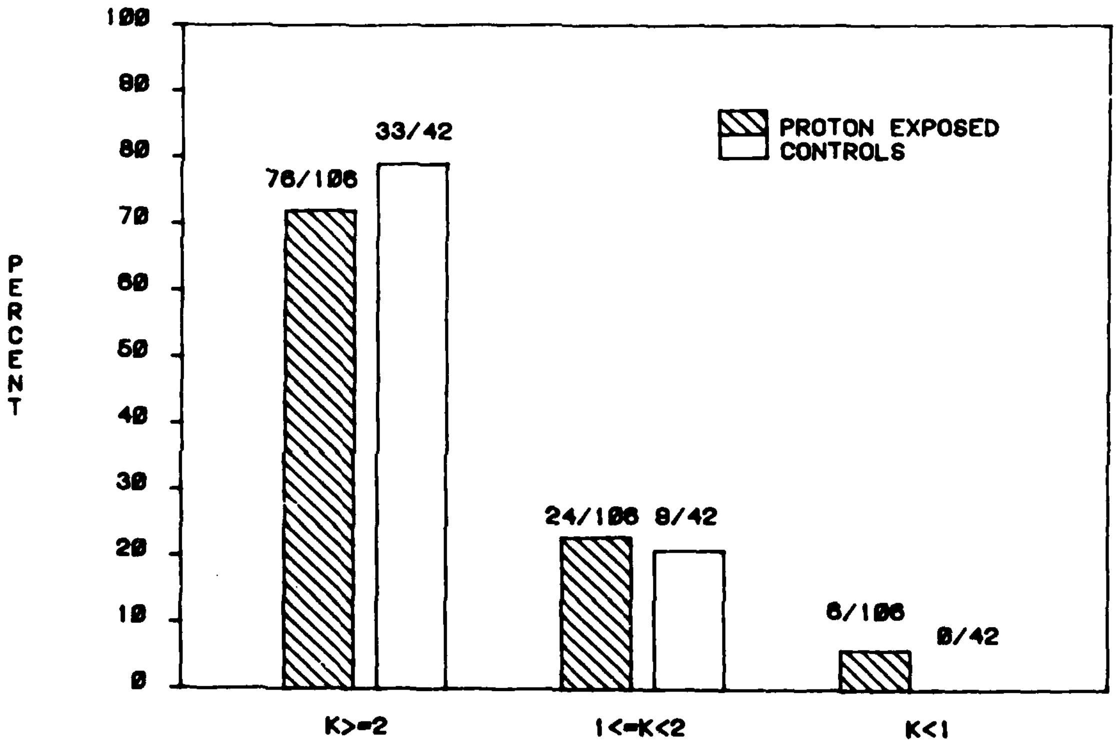

Figure 1. Glucose clearance rate.

Distribution:

K = 2 or more: Normal

K = 1 to 2: Borderline

K = less than 1: Diabetic

DISCUSSION

The lowered glucose tolerance in the 17-20-year-old nonirradiated animals as compared with the 9-11-year-old controls is consistent with the reports of reduced glucose tolerance in normal aging humans. While the average insulin response of the old controls was not significantly different from that of the young controls, there was greater correlation between insulin response and glucose clearance rate in the younger animals (young: r=.78, n=10; Old: r=.17, n=42). A possible explanation for this would be age-related decrease in insulin sensitivity or number of insulin receptor sites available to the plasma insulin. Glucose clearance would then be less dependent on plasma insulin than on the tissue sensitivity to insulin. This finding would seem to disagree with published reports on nonobese glucose-intolerant humans that indicated no decrease in insulin sensitivity, but, rather a relative hypoinsulinemia (8). It should be recognized, however, that none of our control animals was in the category of glucose intolerant as defined in the human studies, i.e., $K < 1.0$.

Considerable heterogeneity in insulin response and insulin sensitivity in human population has been reported (8). Overtly diabetic individuals may be hyperinsulinemic and insulin resistant for a period before the islet cells become unresponsive to glucose challenge.

Given the limitations imposed by small sample groups and conservative statistical analyses, total-body proton irradiation can influence the development of glucose intolerance and adult-onset hyperglycemia. Tables 9 and 10 indicate that energies sufficient to provide uniform dose distribution throughout the body, especially in males, are more effective in promoting glucose intolerance than lower energies. Energies of 138 MeV and above allowed the pancreas to absorb a higher percentage of the surface radiation dose than the lower energies and may have accelerated the loss of responsiveness of the Beta cells to glucose challenge. Although the difference in insulin response could not be confirmed statistically, the average insulin response in the high-energy group was lowest where the corresponding glucose clearance was also low. Among those animals with severely impaired glucose clearance ($K < 1.0$) there was markedly reduced insulin response. This finding is consistent with other observations on macaques with naturally occurring diabetes mellitus (4). Of the six animals in this group, four were exposed to high-energy protons and two were exposed to low-energy protons.

It was not possible to draw any inferences regarding the susceptibility of genetically low insulin responders to radiation-induced glucose intolerance. Although all the animals with severe glucose intolerance had a low insulin response, those irradiated animals with K values in the intermediate or prediabetic range exhibited a wide range of insulin responses. It is doubtful that insulin response to a single intravenous glucose dose would be of value in estimating the degree of glucose intolerance that might be expected as a delayed effect of total-body irradiation.

CONCLUSIONS

Glucose tolerance in rhesus monkeys diminishes as a normal consequence of aging. The progression of glucose intolerance to a hypoinsulinemic, hyperglycemic state analogous to human adult-onset diabetes mellitus can occur in the general population. Total-body proton irradiation, particularly in the energy range providing complete body penetration, appears to increase the probability of development of the diabetic syndrome. It is suggested that this increased probability of diabetes is due to direct effect of the irradiation on the Beta cells of the pancreatic islets.

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TABLE 1. CONTROL GROUP AVERAGE MEASUREMENT ± STANDARD ERRORS

		Protons 20-Year-Olds	Solar flares 17-Year-Olds	Pools 9-11-Year-Olds	Average
Fasting blood glucose (mg/dl)	M	82.3 ±2.6 (21)	79.4 ±5.9 (5)	74.8 ±3.8 (5)	80.7 ±2.1 (31)
	F	72.7 ±2.5 (10)*	72.2 ±5.8 (6)	69.2 ±1.9 (5)	73.7 ±2.2 (21)
Average		79.2 ±2.1 (31)	79.3 ±4.0 (11)	72.0 ±2.2 (10)	77.9 ±1.6 (52)
Fasting insulin (μ-units/ml)	M	63.8 ±6.5 (21)	54.2 ±16.3 (5)	32.6 ±6.3 (5)	57.2 ±5.5 (31)
	F	61.5 ±7.9 (10)*	55.7 ±12.8 (16)	40.4 ±8.5 (5)	54.8 ±5.7 (21)
Average		63.0 ±5.0 (31)	55.0 ±9.7 (11)	36.5 ±5.2 (10)	56.2 ±3.9 (52)
Glucose clearance (%/min)	M	2.43 ±.13 (21)	2.61 ±.12 (5)	3.11 ±.17 (5)	2.57 ±.10 (31)
	F	3.05 ±.22 (10)	2.16 ±.29 (6)	3.36 ±.34 (5)	2.87 ±.18 (21)
Average		2.63 ±.12 (31)	2.37 ±.18 (11)	3.24 ±.19 (10)	2.69 ±.10 (51)
Insulin response (μ-units x min)	M	5953 ±1012 (21)	4084 ±897 (5)	4531 ±1148 (5)	5422 ±727 (31)
	F	7409 ±1586 (10)*	8490 ±2802 (6)	9674 ±3120 (5)	8257 ±1266 (21)
Average		6422 ±849 (31)	6487 ±1664 (11)	7103 ±1787 (10)	6567 ±691 (52)

Number of subjects in each group is in parentheses.
*Count does not include subject for which data was missing.

TABLE 2. SAMPLES TESTED IN THE ORIGINAL PROTON STUDIES

Incident energy (MeV)

	32		55		138		400		2300		Totals	
Dose (rads)	M	F	M	F	M	F	M	F	M	F	M	F
25-113			10	3			7	3	8	3	25	9
200-280	2		6	5	4*		4	4	5	5	21	14
360-400			5	2	4	2	5	2	2	2	16	8
500-650	3*	3	2		2	1	1		1		9	4
Totals	5	3	23	10	10	3	17	9	16	10	71	35

*Count does not include subject for which data was missing.

TABLE 3. AVERAGE MEASUREMENTS FROM THE ORIGINAL PROTON STUDIES ± STANDARD ERRORS

Variable	Sex	Controls	Incident energy (MeV) 32	55	138	400	2300	Total
Fasting blood glucose (mg/dl)	M	81.8 ±2.4 (26)	76.6 ±5.6 (5)	72.4 ±1.5 (23)	80.3 ±2.5 (10)	78.8 ±2.1 (17)	91.0 ±3.6 (16)	80.1 ±1.2 (97)
	F	75.1 ±2.7 (16)	124.0 ±34.0 (3)	87.1 ±9.4 (10)	84.7 ±6.9 (3)	79.4 ±2.6 (9)	85.2 ±6.3 (10)	83.7 ±3.3 (51)
Average		79.2 ±1.8 (42)	94.4 ±14.5 (8)	76.9 ±3.2 (33)	81.3 ±2.4 (13)	79.0 ±1.6 (26)	88.8 ±3.3 (26)	81.3 ±1.4 (148)
Fasting insulin (μ-units/ml)	M	61.9 ±6.0 (26)	40.4 ±13.1 (5)	55.5 ±7.3 (23)	35.8 ±7.7 (10)	38.6 ±2.9 (17)	47.1 ±4.3 (16)	50.1 ±2.8 (97)
	F	59.3 ±6.7 (16)	67.3 ±33.8 (3)	50.7 ±12.4 (10)	20.7 ±7.7 (3)	68.4 ±15.8 (9)	90.3 ±17.9 (10)	63.5 ±6.1 (51)
Average		60.9 ±4.4 (42)	50.5 ±14.4 (8)	54.1 ±6.2 (33)	32.3 ±1.6 (13)	49.0 ±6.3 (26)	63.7 ±8.3 (26)	54.7 ±2.8 (148)
Glucose clearance (%/min)	M	2.47 ±.11 (26)	2.71 ±.27 (5)	2.70 ±.13 (23)	2.36 ±.17 (10)	2.23 ±.16 (17)	2.24 ±.16 (16)	2.44 ±.06 (97)
	F	2.72 ±.20 (16)	1.62 ±.59 (3)	2.30 ±.24 (10)	1.54 ±.58 (3)	2.28 ±.25 (9)	2.22 ±.21 (10)	2.33 ±.12 (51)
Average		2.56 ±.10 (6)	2.30 ±.32 (8)	2.58 ±.12 (33)	2.58 ±.17 (13)	2.25 ±.13 (26)	2.23 ±.12 (26)	2.40 ±.06 (148)
Insulin response (μ-units x min)	M	5593 ±841 (26)	5837 ±1424 (5)	6097 ±523 (23)	3452 ±607 (10)	3426 ±501 (17)	4337 ±1147 (16)	4917 ±355 (97)
	F	7814 ±1394 (16)	4278 ±3691 (3)	4845 ±1043 (10)	2566 ±2434 (3)	9337 ±2618 (9)	5315 ±966 (10)	6494 ±757 (51)
Average		6439 ±752 (42)	5252 ±1505 (8)	5718 ±488 (33)	3248 ±901 (13)	5472 ±1087 (26)	4713 ±790 (26)	5461 ±353 (148)

Number of subjects in each group is in parentheses.

TABLE 4. AVERAGE MEASUREMENTS FROM THE ORIGINAL PROTON STUDIES ± STANDARD ERRORS

Variable	Sex	Dose Groupings (rads) Controls	25-113	200-280	360-400	500-650	Average
Fasting blood glucose (mg/dl)	M	81.8 ±2.4 (26)	77.7 ±2.1 (25)	82.1 ±3.0 (21)	78.8 ±2.4 (16)	80.0 ±5.5 (9)	80.1 ±1.2 (97)
	F	75.1 ±2.7 (16)	90.3 ±10.4 (9)	83.3 ±4.3 (14)	80.0 ±16.6 (8)	111.3 ±27.2 (4)	83.7 ±3.3 (51)
Average		79.2 ±1.8 (42)	81.0 ±3.2 (34)	82.6 ±2.4 (35)	79.2 ±2.1 (24)	89.6 ±9.4 (13)	81.3 ±1.4 (148)
Fasting insulin (μ-units/ml)	M	61.9 ±6.0 (26)	54.6 ±1.5 (25)	43.2 ±4.3 (21)	36.9 ±4.3 (16)	42.6 ±8.0 (9)	50.1 ±2.8 (97)
	F	59.3 ±6.7 (16)	57.7 ±10.8 (9)	85.9 ±15.0 (14)	41.9 ±16.9 (8)	58.5 ±25.5 (4)	63.5 ±6.1 (51)
Average		60.9 ±4.4 (42)	55.4 ±5.6 (34)	60.3 ±7.3 (35)	38.6 ±5.9 (24)	47.5 ±9.2 (13)	54.7 ±2.8 (148)
Glucose clearance (%/min)	M	2.47 ±.11 (26)	2.53 ±.14 (25)	2.46 ±.14 (21)	2.26 ±.15 (16)	2.42 .18 (9)	2.4 ±.06 (97)
	F	2.72 ±.20 (16)	2.36 ±.23 (9)	2.25 ±.20 (14)	1.86 ±.30 (8)	1.89 ±.49 (4)	2.3 ±.12 (51)
Average		2.56 ±.10 (42)	2.48 ±.12 (34)	2.38 ±.12 (35)	2.13 ±.14 (24)	2.26 ±.20 (13)	2.40 ±.06 (148)
Insulin response (μ-units x min)	M	5593 ±841 (26)	4717 ±580 (25)	5436 ±868 (21)	3796 ±486 (16)	4306 ±1155 (9)	4917 ±355 (97)
	F	7814 ±1394 (16)	4343 ±1105 (9)	7771 ±1543 (14)	4754 ±2157 (8)	5063 ±2726 (4)	6494 ±757 (51)
Average		6439 ±752 (42)	4618 ±509 (34)	6370 ±818 (35)	4115 ±764 (24)	4539 ±1094 (13)	5461 ±353 (148)

Number of subjects in each group is in parentheses.

TABLE 5. AVERAGE FASTING BLOOD GLUCOSE (mg/dl) ± STANDARD ERRORS

Dose (rads)		Incident energy (MeV) 32	55	138	400	2300	Average
25-113	M		72.0 ±2.5 (10)		80.6 ±4.6 (7)	82.3 ±3.2 (8)	77.7 ±2.1 (25)
	F		101.7 ±33.7 (3)		83.0 ±2.9 (3)	86.3 ±6.4 (3)	90.3 ±10.4 (9)
200-280	M	82.5 ±14.5 (2)	72.5 ±3.4 (6)	82.0 ±6.1 (4)	79.3 ±2.3 (4)	96.0 ±6.5 (5)	82.1 ±3.0 (21)
	F		78.0 ±1.3 (5)		80.0 ±3.8 (4)	91.2 ±11.4 (5)	83.3 ±4.3 (14)
360-400	M		73.6 ±2.3 (5)	78.5 ±2.3 (4)	76.0 ±3.2 (5)	99.0 ±6.0 (2)	78.8 ±2.4 (16)
	F		88.0 ±1.0 (2)	90.5 ±6.5 (2)	73.0 ±8.0 (2)	68.5 ±1.5 (2)	80.0 ±4.1 (8)
500-650	M	72.7 ±4.1 (3)	71.0 ±8.0 (2)	80.5 ±3.2 (2)	79.0 ±0.0 (1)	120.0 ±0.0 (1)	80.0 ±5.5 (9)
	F	124.0 ±34.0 (3)		73.0 ±0.0 (1)			111.3 ±3.7 (4)
Average	M	76.6 ±5.6 (5)	72.4 ±1.5 (23)	80.3 ±2.5 (10)	78.8 ±2.1 (17)	91.0 ±3.6 (16)	79.5 ±1.4 (71)
	F	124.0 ±34.0 (3)	87.1 ±9.4 (10)	84.7 ±6.9 (3)	79.4 ±2.6 (9)	85.2 ±6.3 (10)	87.5 ±4.5 (35)

Number of subjects in each group is in parentheses.

TABLE 6. AVERAGE FASTING INSULIN (μ-units/ml) ± STANDARD ERRORS

Dose (rads)		Incident energy (MeV) 32	55	138	400	2300	Average
25-113	M		72.9 ±13.6 (10)		34.6 ±3.9 (7)	49.4 ±6.6 (8)	54.6 ±6.6 (25)
	F		25.3 ±6.7 (3)		76.3 ±23.8 (3)	71.3 ±2.4 (3)	57.7 ±10.8 (9)
200-280	M	59.0 ±31.0 (2)	39.5 ±6.9 (6)	44.5 ±13.1 (4)	43.5 ±3.2 (4)	40.2 ±2.8 (5)	43.2 ±4.3 (21)
	F		51.0 ±7.7 (5)		80.3 ±30.0 (4)	125.2 ±27.2 (5)	85.9 ±15.0 (14)
360-400	M		32.6 ±5.0 (5)	34.3 ±14.4 (4)	35.0 ±4.9 (5)	58.0 ±4.0 (2)	36.9 ±4.3 (16)
	F		88.0 ±62.0 (2)	15.0 ±9.0 (2)	33.0 ±16.0 (2)	31.5 ±4.5 (2)	41.9 ±16.1 (8)
500-650	M	28.0 ±7.8 (3)	74.0 ±8.0 (2)	21.5 ±2.5 (2)	66.1 ±0.0 (1)	42.0 ±0.0 (1)	42.6 ±8.0 (9)
	F	67.3 ±33.8 (3)		32.0 ±0.0 (1)			58.5 ±25.5 (4)
Average	M	40.4 ±13.1 (5)	55.5 ±7.3 (23)	35.8 ±7.7 (10)	38.7 ±2.9 (17)	47.1 ±4.3 (16)	45.8 ±3.1 (71)
	F	67.3 ±33.8 (3)	50.7 ±12.4 (10)	20.7 ±7.7 (3)	68.4 ±15.8 (9)	90.3 ±17.9 (10)	65.4 ±8.3 (35)

Number of subjects in each group is in parentheses.

TABLE 7. AVERAGE GLUCOSE CLEARANCE (%/min) ± STANDARD ERRORS

		Incident energy (MeV)					
Dose (rads)		32	55	138	400	2300	Average
25-113	M		3.01 ±.21 (10)		2.15 ±.28 (7)	2.25 ±.13 (8)	2.53 ±.14 (25)
	F		1.97 ±.62 (3)		2.55 ±.29 (3)	2.54 ±.20 (3)	2.36 ±.23 (9)
200-280	M	2.41 ±.65 (2)	2.58 ±.18 (6)	2.40 ±.12 (4)	2.86 ±.18 (4)	2.08 ±.47 (5)	2.46 ±.14 (21)
	F		2.27 ±.27 (5)		2.43 ±.46 (4)	2.10 ±.38 (5)	2.25 ±.20 (14)
360-400	M		2.52 ±.10 (5)	2.38 ±.43 (4)	1.75 ±.23 (5)	2.63 ±.02 (2)	2.26 ±.15 (16)
	F		2.86 ±.55 (2)	.97 ±.01 (2)	1.58 ±.07 (2)	2.03 ±.53 (2)	1.86 ±.30 (8)
500-650	M	2.90 ±.24 (3)	1.95 ±.50 (2)	2.12 ±.27 (2)	2.72 ±0.0 (1)	2.22 ±0.0 (1)	2.42 ±.18 (9)
	F	1.62 ±.596 (3)		2.69 ±0.0 (1)			1.89 ±.49 (4)
Average	M	2.71 ±.27 (5)	2.70 ±.13 (23)	2.22 ±.17 (10)	2.23 ±.16 (17)	2.24 ±.16 (16)	2.43 ±.08 (71)
	F	1.62 ±.59 (3)	2.30 ±.24 (10)	1.54 ±.58 (3)	2.28 ±.25 (9)	2.22 ±.21 (10)	2.15 ±.13 (35)

Number of subjects in each group is in parentheses.

TABLE 8. AVERAGE INSULIN RESPONSE (μ-units x min) ± STANDARD ERRORS

Dose (rads)		32	55	138	400	2300	Average
		Incident energy (MeV)					
25-113	M		5810 ±807 (10)		2646 ±601 (7)	5165 ±1230 (8)	4717 ±580 (25)
	F		2338 ±955 (3)		5034 ±1709 (3)	5656 ±2776 (3)	4343 ±1105 (9)
200-280	M	4344 ±1836 (2)	6904 ±1505 (6)	4299 ±1273 (4)	5549 ±854 (4)	4930 ±3097 (5)	5436 ±868 (21)
	F		6316 ±1662 (5)		11650 ±4767 (4)	6126 ±1027 (5)	7771 ±1543 (14)
360-400	M		5688 ±704 (5)	2838 ±810 (4)	3672 ±428 (5)	1290 ±726 (2)	3796 ±486 (16)
	F		4929 ±1947 (2)	141 ±351 (2)	11170 ±7743 (2)	2778 ±306 (2)	4754 ±2157 (8)
500-650	M	6832 ±2099 (3)	6138 ±654 (2)	2988 ±732 (2)	836 ±0 (1)	842 ±0 (1)	4306 ±1155 (9)
	F	4278 ±3691 (3)		7416 ±0 (1)			5063 ±2726 (4)
Average	M	5837 ±1425 (5)	6097 ±532 (23)	3452 ±607 (10)	3426 ±501 (17)	4336 ±1147 (16)	4670 ±375 (71)
	F	4278 ±3691 (3)	4845 ±1043 (10)	2566 ±2433 (3)	9337 ±2434 (9)	5315 ±966 (10)	5890 ±896 (35)

Number of subjects in each group is in parentheses.

TABLE 9. SUMMARY OF SIGNIFICANT DIFFERENCES IN ALL MEASUREMENTS BETWEEN DOSE-ENERGY GROUPS

Incident energy (MeV)	Dose (rads) 25-113	200-280	360-400	500-650
32 MeV	-	N.S. (2 females)	-	FI: M<M Controls (B) FBG: F>F Controls (A) K: F<F Controls (B)
55 MeV	FBG: M<M Controls (A) K: M>M Controls (A) FI: M>M 360-400 rads (A) FI, K, IR: M>F (B)	FBG: M<2300 MeV M (A) FI: F<2300 MeV F (A)	FBG: M<F (A) FBG: M<2300 MeV M (A) FI: M<25-113 rads M (A)	N.S. (2 males)
138 MeV	-	N.S. (4 males)	FI,K: MF<MF Controls (A) K: MF<500-650 rads MF (A)	K: MF>360-400 rads MF (A
400 MeV	FI: M<F (A)	K: MF>360-400 rads MF (A)	K: MF<MF Controls (A) K: MF<MF 200-280 rads (A)	N.S. (1 male)
2300 MeV	FI: M<F (B)	FBG: M>M Control (A) FI: F>F Control (A) FI: F>F 360-400 rads (A) FI: M<F (A) FBG: M>55 MeV M (A) FI: F>55 MeV F (A)	FBG: M>M 55 MeV (A) FI: F<F 200-280 rads (A)	N.S. (1 male)

FBG = fasting blood glucose
K = glucose clearance rate
FI = fasting insulin
IR = insulin response
M = male
F = female
MF = males + females
(A) = $p < .05$
(B) = $p < .10$
\- = no data for testing
N.S.( ) = not significant with the number of subjects available for testing in parentheses

TABLE 10. AVERAGE MEASUREMENTS ± STANDARD ERRORS GROUPED ACCORDING TO LEVEL

		Dose (rads)							
		25-113		200-280		360-400		500-650	
		M	F	M	F	M	F	M	F
Fasting blood glucose (FBG) (mg/dl)	H	81.5 ±2.7 (15)	84.7 ±3.2 (6)	86.5 ±3.7 (13)	86.2 ±6.5 (9)	81.1 ±3.2 (11)	77.3 ±5.0 (6)	90.0 ±10.1 (4)	73.0 ±0.0 (1)
	L	72.0 ±2.5 (10)	101.7 ±33.7 (3)	75.0 ±4.1 (8)	78.0 ±1.3 (5)	73.6 ±2.3 (5)	88.0 ±1.0 (2)	72.0 ±3.4 (5)	124.0 ±34.0 (3)
Average		77.7 ±2.1 (25)	90.3 ± 10.4 (9)	82.1 ±3.0 (21)	83.3 ±1.3 (14)	78.8 ±2.4 (16)	80.0 ±4.1 (8)	80.0 ±5.5 (9)	111.3 ±27.2 (4)
		M	F	M	F	M	F	M	F
Fasting insulin (FI) (μ-units/ml)	H	42.5 ±4.3 (15)	73.8 ±10.8 (6)	42.5 ±4.8 (13)	105.2 ±20.4 (9)	38.9 ±5.9 (11)	26.5 ±6.1 (6)	37.8 ±10.6 (4)	32.0 ±0.0 (1)
	L	72.9 ±13.6 (10)	25.3 ±6.7 (3)	44.4 ±8.4 (8)	51.0 ±7.7 (5)	32.6 ±5.0 (5)	88.0 ±62.0 (2)	46.4 ±12.3 (5)	67.3 ±33.8 (3)
Average		54.6 ±6.6 (25)	57.7 ±10.8 (9)	43.2 ±4.3 (21)	85.8 ±15.0 (14)	36.9 ±4.3 (16)	41.9 ±16.1 (8)	42.6 ±8.0 (9)	58.5 ±25.5 (4)
		M	F	M	F	M	F	M	F
Glucose clearance (K) (%/min)	H	2.20 ±.13 (15)	2.55 ±.16 (6)	2.41 ±.20 (13)	2.24 ±.28 (9)	2.14 ±.21 (11)	1.53 ±.24 (6)	2.29 ±.18 (4)	2.60 ±0.00 (1)
	L	3.01 ±.21 (10)	1.97 ±.62 (3)	2.53 ±.18 (8)	2.27 ±.27 (5)	2.48 ±.10 (5)	2.85 ±.54 (2)	2.52 ±.31 (5)	1.62 ±.58 (3)
Average		2.52 ±.14 (25)	2.36 ±.23 (9)	2.46 ± .14 (21)	2.25 ±.20 (14)	2.25 ±.15 (16)	1.86 ±.30 (8)	2.42 ±.18 (9)	1.87 ±.48 (4)
		M	F	M	F	M	F	M	F
Insulin response (IR) (μ-units x min)	H	3989 ±767 (15)	5345 ±1464 (6)	4926 ±1196 (13)	8580 ±2241 (9)	2936 ±434 (11)	4696 ±2904 (6)	1496 ±974 (4)	7416 ± 0 (1)
	L	5810 ±808 (10)	2338 ±955 (3)	6264 ±1229 (8)	6316 ±1661 (5)	5688 ±704 (5)	4929 ±1947 (2)	6554 ±1180 (5)	4278 ±3691 (3)
Average		4717 ±581 (25)	4343 ±1105 (9)	5438 ±868 (21)	7771 ±1543 (14)	3796 ±486 (16)	4754 ±2157 (8)	4306 ±1155 (9)	5063 ±27[illegible] (4)

L = low energy, partially penetrating protons; H = high energy, totally penetrating protons.
Number of subjects in each group is in parentheses.

APPENDIX A

EXPOSURE DATA

GLUCOSE DATA

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
79C	F	POOL	CONTROL	*-Jan-82	74	43	21.4	3.22	7200	380
N47	F	POOL	CONTROL	*-Jan-82	64	68	21.3	3.24	15624	850
675A	F	POOL	CONTROL	*-Jan-82	73	32	27.1	2.55	4536	200
617A	F	POOL	CONTROL	*-Jan-82	68	43	14.9	4.64	18426	600
448C	M	POOL	CONTROL	*-Jan-82	63	43	20.1	3.44	7026	270
593B	F	POOL	CONTROL	*-Jan-82	67	16	21.8	3.17	2586	94
896A	M	POOL	CONTROL	*-Jan-82	82	33	21.9	3.16	5634	230
918B	M	POOL	CONTROL	*-Jan-82	72	10	25.1	2.75	2604	96
596B	M	POOL	CONTROL	*-Jan-82	73	31	19.8	3.49	6324	270
566B	M	POOL	CONTROL	*-Jan-82	84	46	25.6	2.70	1068	108
11S	F	2 MEV E	CONTROL	4-Nov-69	73	54	25.6	2.71	12288	500
67R	F	2 MEV E	CONTROL	4-Nov-69	81	16	45.9	1.51	3900	105
69R	F	2 MEV E	CONTROL	4-Nov-69	63	86	28.0	2.47	19836	880
S11	F	2 MEV X	CONTROL	1-May-65	103	20	60.1	1.15	522	36
15E	F	5 MEV	CONTROL	10-Apr-68	80	34	23.1	2.99	2418	119
36P	M	5 MEV	CONTROL	10-Apr-68	81	96	36.6	1.89	17196	440
3V4	M	5 MEV	CONTROL	1-Jun-67	79	42	32.0	2.16	5058	200
61S	F	5 MEV	CONTROL	5-Dec-69	62	49	18.0	3.85	11562	500
6P5	F	5 MEV	CONTROL	2-Jun-67	72	88	34.1	2.03	900	150
DL2	M	5 MEV	CONTROL	5-Dec-69	69	36	25.2	2.74	11652	340
EJ4	M	5 MEV	CONTROL	5-Dec-69	74	51	39.1	1.77	4806	238
V86	M	55 MEV	CONTROL	30-Apr-65	71	43	18.3	3.77	6414	250
P46	M	55 MEV	CONTROL	30-Apr-65	78	34	33.4	2.07	5304	150
U74	M	55 MEV	CONTROL	30-Apr-65	72	47	38.3	1.81	11262	340
U76	M	55 MEV	CONTROL	30-Apr-65	75	68	37.3	1.86	13068	340
U96	M	55 MEV	CONTROL	30-Apr-65	93	125	30.5	2.27	4140	250
V02	M	55 MEV	CONTROL	30-Apr-65	114	103	50.5	1.37	558	146
J07	F	138 MEV	CONTROL	20-Jan-65	76	86	18.8	3.68	3288	315
J12	M	138 MEV	CONTROL	20-Jan-65	74	34	22.0	3.15	4116	170
J17	F	138 MEV	CONTROL	20-Jan-65	70	58	20.1	3.44	10308	340
L16	M	138 MEV	CONTROL	1-Jan-65	70	33	29.6	2.34	3678	132
L22	M	138 MEV	CONTROL	20-Jan-65	77	41	21.5	3.21	4146	170
Q12	M	400 MEV	CONTROL	18-Mar-65	85	35	23.7	2.91	4614	170
R39	F	400 MEV	CONTROL	18-Mar-65	84	90	22.8	3.03	16200	700

GLUCOSE DATA

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
R41	F	400 MEV	CONTROL	18-Mar-65	68	50	21.5	3.22	7512	250
S66	M	400 MEV	CONTROL	18-Mar-65	93	108	27.1	2.55	13908	600
S69	F	400 MEV	CONTROL	18-Mar-65	60	15	37.9	1.83	2712	91
S99	F	400 MEV	CONTROL	1-Mar-65	80	73	25.6	2.70	11526	520
T68	M	400 MEV	CONTROL	18-Mar-65	94	70	24.4	2.83	504	105
T70	M	400 MEV	CONTROL	18-Mar-65	96	110	27.8	2.48	2988	200
OA4	M	2300 MEV	CONTROL	10-Oct-65	82	50	37.3	1.85	2544	140
6AO	M	2300 MEV	CONTROL	10-Oct-65	88	54	23.4	2.95	4236	192
U08	M	2300 MEV	CONTROL	10-Oct-65	97	86	23.8	2.91	3390	230
U22	M	2300 MEV	CONTROL	10-Oct-65	67	73	32.2	2.15	1422	175
W43	F	2300 MEV	CONTROL	1-Oct-65	75	72	18.3	3.77	7662	290
O4N	M	SOLAR FLARE	CONTROL	20-Apr-69	103	78	23.5	2.94	3948	190
7X7	F	SOLAR FLARE	CONTROL	1-Apr-69	86	84	23.0	3.01	8700	400
8X5	F	SOLAR FLARE	CONTROL	20-Apr-69	69	74	32.5	2.13	5694	230
ASO	M	SOLAR FLARE	CONTROL	20-Apr-69	72	21	27.3	2.53	2346	77
AW4	M	SOLAR FLARE	CONTROL	20-Apr-69	73	23	24.5	2.82	2142	96
BH6	M	SOLAR FLARE	CONTROL	20-Apr-69	73	44	28.3	2.45	4992	180
HO4	M	SOLAR FLARE	CONTROL	20-Apr-69	76	105	30.0	2.30	6990	280
O2K	M	1.6 MEV	1000	14-May-68	74	15	25.5	2.72	2370	490
36L	M	1.6 MEV	1000	15-May-68	77	27	24.9	2.78	3900	130
44N	M	1.6 MEV	1000	13-May-68	69	31	26.8	2.58	5400	180
78M	M	1.6 MEV	1000	15-May-68	72	38	41.0	1.69	3924	135
J16	M	2 MEV X	360	1-Apr-64	87	28	20.9	3.31	4320	190
E91	F	2 MEV X	446	1-Apr-64	242	30	63.1	1.10	-402	30
K38	M	2 MEV X	446	30-Mar-64	94	143	20.4	3.38	18678	700
R85	F	2 MEV X	446	5-Apr-64	234	27	79.9	0.87	-60	32
F51	F	2 MEV X	538	30-Mar-64	54	25	30.0	2.31	4206	122
G17	F	2 MEV X	538	30-Mar-64	184	37	79.7	0.87	78	40
E41	F	2 MEV X	624	30-Mar-64	316	0	144.0	0.48	0	0
G66	M	2 MEV X	624	25-Mar-64	93	98	29.7	2.33	7710	300
K30	M	2 MEV X	624	1-Apr-64	74	52	25.3	2.74	3960	155
O3R	F	2 MEV E	900	4-Nov-69	76	26	26.3	2.63	4026	146
DV4	M	2 MEV E	900	4-Nov-69	69	25	37.7	1.84	3402	125
EC4	M	2 MEV E	900	4-Nov-69	70	35	19.8	3.49	7638	250

GLUCOSE DATA

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
57R	F	2 MEV E	1200	4-Nov-69	70	125	21.5	3.22	7950	380
65R	F	2 MEV E	1200	4-Nov-69	78	40	20.3	3.40	12816	540
99J	F	2 MEV E	1200	4-Nov-69	83	43	35.6	1.94	3942	220
EL6	M	2 MEV E	1200	4-Nov-69	74	32	26.1	2.65	4470	143
19R	F	2 MEV E	1500	4-Nov-69	61	70	22.0	3.14	8340	360
ED2	M	2 MEV E	1500	4-Nov-69	68	66	21.8	3.18	5436	230
E88	M	32 MEV	280	28-Jul-64	68	28	22.6	3.06	2508	127
F30	M	32 MEV	280	28-Jul-64	97	90	39.3	1.76	6180	220
E93	F	32 MEV	560	27-Jul-64	109	58	48.4	1.43	888	94
F13	F	32 MEV	560	28-Jul-64	189	14	97.8	0.71	294	23
F71	F	32 MEV	560	1-Jul-64	74	130	25.5	2.71	11652	450
G86	M	32 MEV	560	28-Jul-64	74	43	20.4	3.38	8916	430
J70	M	32 MEV	560	27-Jul-64	79	24	25.3	2.73	8946	280
J82	M	32 MEV	560	28-Jul-64	65	17	26.6	2.60	2634	125
266D	M	55 MEV	25	1-May-65	65	120	23.8	2.90	6180	340
Q32	M	55 MEV	25	2-May-65	85	80	23.2	2.99	5838	340
R78	M	55 MEV	25	2-May-65	69	78	28.5	2.42	5118	230
U94	M	55 MEV	25	30-Apr-65	68	136	19.9	3.48	9012	360
V04	M	55 MEV	25	30-Apr-65	68	126	23.1	2.99	9204	430
L91	F	55 MEV	50	2-May-65	169	12	93.8	0.74	480	40
M04	M	55 MEV	50	2-May-65	82	72	30.0	2.31	7572	250
R97	F	55 MEV	50	30-Apr-65	71	32	26.7	2.59	2886	110
U00	M	55 MEV	50	30-Apr-65	66	27	16.7	4.13	6462	230
J51	F	55 MEV	100	2-May-65	65	32	26.7	2.59	3648	190
N76	M	55 MEV	100	1-May-65	62	27	18.3	3.77	4788	210
U14	M	55 MEV	100	1-May-65	77	32	22.5	3.07	918	115
U20	M	55 MEV	100	1-May-65	78	31	34.0	2.03	3006	110
P79	F	55 MEV	200	2-May-65	77	48	40.1	1.73	10344	530
P91	F	55 MEV	200	2-May-65	74	41	23.9	2.89	9894	275
R38	M	55 MEV	200	2-May-65	69	54	29.8	2.32	12504	380
T05	F	55 MEV	200	30-Apr-65	77	80	26.2	2.64	5880	275
T55	F	55 MEV	200	1-May-65	81	50	44.7	1.55	2364	130
T79	F	55 MEV	200	1-May-65	81	36	27.1	2.55	3096	160
U82	M	55 MEV	200	30-Apr-65	64	24	22.5	3.08	3984	150

GLUCOSE DATE

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
U92	M	55 MEV	200	30-Apr-65	68	60	30.2	2.29	9120	260
V30	M	55 MEV	200	1-May-65	68	16	26.0	2.66	2322	90
V52	M	55 MEV	200	1-May-65	85	40	34.6	2.00	5712	180
W50	M	55 MEV	200	30-Apr-65	81	43	22.3	3.10	7782	260
R60	M	55 MEV	400	2-May-65	73	18	26.4	2.62	3324	110
T53	F	55 MEV	400	2-May-65	87	150	30.0	2.31	6876	380
T87	F	55 MEV	400	1-May-65	89	26	20.3	3.40	2982	140
U04	M	55 MEV	400	30-Apr-65	68	33	30.6	2.26	5592	160
U48	M	55 MEV	400	30-Apr-65	81	26	25.4	2.73	6924	220
U70	M	55 MEV	400	30-Apr-65	76	46	29.6	2.33	7308	230
V96	M	55 MEV	400	2-May-65	70	40	25.9	2.67	5292	210
U78	M	55 MEV	600	30-Apr-65	63	66	47.7	1.45	5484	200
V22	M	55 MEV	600	1-May-65	79	82	28.2	2.45	6792	270
G96	M	138 MEV	210	19-Jan-65	96	77	28.6	2.42	3426	240
K48	M	138 MEV	210	20-Jan-65	75	20	28.3	2.44	2664	100
K70	M	138 MEV	210	21-Jan-65	69	54	26.0	2.65	8088	250
K84	M	138 MEV	210	20-Jan-65	88	27	33.4	2.07	3018	100
J84	M	138 MEV	360	19-Jan-65	73	15	20.4	3.39	2796	125
K13	F	138 MEV	360	21-Jan-65	84	6	71.5	0.97	492	19
K44	M	138 MEV	360	19-Jan-65	78	24	25.2	2.74	1464	65
L19	F	138 MEV	360	21-Jan-65	97	24	72.5	0.96	-210	24
L28	M	138 MEV	360	21-Jan-65	79	21	35.3	1.96	1968	76
L50	M	138 MEV	360	20-Jan-65	84	77	47.9	1.44	5124	195
J64	M	138 MEV	500	20 Jan-65	84	19	37.5	1.85	3720	108
J80	M	138 MEV	500	20-Jan-65	77	24	28.9	2.39	2256	86
K71	F	138 MEV	500	20-Jan-65	73	32	25.7	2.69	7416	240
L32	M	400 MEV	50	20-Mar-65	71	40	34.4	2.01	966	70
P12	M	400 MEV	50	20-Mar-65	69	35	24.5	2.82	4614	105
L74	M	400 MEV	100	18-Mar-65	89	40	67.1	1.03	708	190
L78	M	400 MEV	100	18-Mar-65	85	41	25.3	2.73	2730	135
L92	M	400 MEV	100	18-Mar-65	98	45	39.2	1.76	1734	90
P04	M	400 MEV	100	20-Mar-65	87	24	24.3	2.84	3240	126
Q03	F	400 MEV	100	17-Mar-65	83	120	24.2	2.86	5850	250
R71	F	400 MEV	100	20-Mar-65	78	71	24.4	2.83	7500	360
S73	F	400 MEV	100	17-Mar-65	88	38	35.0	1.97	1752	86

GLUCOSE DATA

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
T62	M	400 MEV	100	18-Mar-65	65	17	37.0	1.87	4530	123
L99	F	400 MEV	200	18-Mar-65	69	52	23.2	2.98	20232	520
M15	F	400 MEV	200	17-Mar-65	85	54	21.1	3.27	3768	230
M16	M	400 MEV	200	17-Mar-65	79	52	27.4	2.53	7908	340
P23	F	400 MEV	200	18-Mar-65	81	45	58.1	1.19	3030	140
S43	F	400 MEV	200	14-Mar-65	85	170	30.7	2.26	19560	800
S60	M	400 MEV	200	17-Mar-65	81	45	25.0	2.76	4776	250
S68	M	400 MEV	200	18-Mar-65	73	38	20.5	3.37	3942	145
T74	M	400 MEV	200	18-Mar-65	84	39	25.0	2.76	5568	220
F88	M	400 MEV	400	17-Mar-65	66	35	28.0	2.47	4386	160
G04	M	400 MEV	400	18-Mar-65	84	20	54.8	1.26	3348	108
L87	F	400 MEV	400	18-Mar-65	81	49	42.0	1.65	3426	130
M17	F	400 MEV	400	17-Mar-65	65	17	45.9	1.51	18912	160
M30	M	400 MEV	400	17-Mar-65	72	41	35.0	1.97	3342	119
P72	M	400 MEV	400	18-Mar-65	78	30	54.7	1.27	2430	82
R08	M	400 MEV	400	20-Mar-65	80	49	38.9	1.78	4854	160
L84	M	400 MEV	600	15-Mar-65	79	66	25.5	2.71	-834	83
T49	F	2300 MEV	56	12-Oct-65	81	70	30.7	2.25	3192	150
U45	F	2300 MEV	56	10-Oct-65	79	68	23.7	2.92	11196	500
U47	F	2300 MEV	56	10-Oct-65	99	76	28.1	2.46	2580	192
W26	M	2300 MEV	56	10-Oct-65	96	26	41.2	1.68	2718	93
6A8	M	2300 MEV	113	12-Oct-65	85	46	26.1	2.66	3954	160
U64	M	2300 MEV	113	12-Oct-65	81	78	28.2	2.45	12918	370
V72	M	2300 MEV	113	11-Oct-65	81	65	40.1	1.72	2430	124
V74	M	2300 MEV	113	12-Oct-65	81	66	28.4	2.44	3738	210
V76	M	2300 MEV	113	10-Oct-65	69	36	26.5	2.62	4218	175
V88	M	2300 MEV	113	10-Oct-65	92	30	32.4	2.13	3912	120
W04	M	2300 MEV	113	10-Oct-65	73	48	30.5	2.27	7428	208
OA2	M	2300 MEV	225	11-Oct-65	81	72	24.0	2.88	17112	490
S53	F	2300 MEV	225	10-Oct-65	73	92	32.7	2.11	5460	230
U15	F	2300 MEV	225	10-Oct-65	70	60	22.9	3.02	4308	200
U21	F	2300 MEV	225	28-Sep-65	134	94	84.0	0.82	3792	173
U49	F	2300 MEV	225	11-Oct-65	89	185	36.8	1.88	8910	400
V46	M	2300 MEV	225	12-Oct-65	94	27	30.0	2.31	2148	96

GLUCOSE DATA

ID	SEX	ENERGY	DOSE	IRDATE	FBG	FI	HL	K	IR	IMAX
V98	M	2300 MEV	225	10-Oct-65	87	29	21.7	3.18	3612	150
W30	M	2300 MEV	225	28-Sep-65	99	43	55.5	1.24	1710	82
W33	F	2300 MEV	225	12-Oct-65	90	195	25.9	2.67	8160	450
W34	M	2300 MEV	225	12-Oct-65	119	30	90.4	0.77	66	36
1A2	M	2300 MEV	395	11-Oct-65	105	54	26.5	2.61	564	88
U51	F	2300 MEV	395	10-Oct-65	67	36	46.3	1.50	2472	110
V51	F	2300 MEV	395	11-Oct-65	70	27	27.1	2.56	3084	161
W32	M	2300 MEV	395	12-Oct-65	93	62	26.1	2.65	2016	125
U16	M	2300 MEV	560	10-Oct-65	120	42	31.1	2.22	840	77
BC0	M	SOLAR FLARE	300	20-Apr-69	67	44	25.0	2.77	5940	190
07K	F	SOLAR FLARE	300	20-Apr-69	77	88	27.8	2.48	6708	250
AY4	M	SOLAR FLARE	300	20-Apr-69	83	66	20.9	3.30	2616	205
BE2	M	SOLAR FLARE	300	20-Apr-69	71	38	32.5	2.13	4464	140
BH4	M	SOLAR FLARE	300	20-Apr-69	73	31	25.7	2.69	4974	170
H28	M	SOLAR FLARE	300	20-Apr-69	66	43	21.2	3.27	4530	230
BE6	M	SOLAR FLARE	600	22-Apr-69	76	28	25.4	2.72	4164	145
BQ8	M	SOLAR FLARE	600	20-Apr-69	89	32	46.4	1.49	3678	103
BV6	M	SOLAR FLARE	600	20-Apr-69	73	58	25.9	2.67	8436	300
H40	M	SOLAR FLARE	600	20-Apr-69	74	32	24.1	2.87	4782	180
05C	F	SOLAR FLARE	900	20-Apr-69	89	150	28.9	2.39	16860	560
87H	F	SOLAR FLARE	900	20-Apr-69	82	340	32.8	2.11	11820	800
93G	F	SOLAR FLARE	900	20-Apr-69	80	70	26.4	2.62	5160	220
AW0	M	SOLAR FLARE	900	20-Apr-69	78	54	21.6	3.20	6108	250
BH8	M	SOLAR FLARE	900	20-Apr-69	119	80	38.3	1.81	4824	208
BL6	M	SOLAR FLARE	900	20-Apr-69	68	22	23.9	2.89	3078	125
41J	F	SOLAR FLARE	1200	22-Apr-69	64	58	23.1	3.00	7644	340
67J	F	SOLAR FLARE	1200	20-Apr-69	66	103	38.2	1.81	7933	370
AB8	M	SOLAR FLARE	1200	22-Apr-69	88	85	23.2	2.98	6054	340
AW6	M	SOLAR FLARE	1200	22-Apr-69	75	40	36.5	1.90	4236	147

END

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